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Development and Testing of the Pyrotechnic Subsystem for the Mariner Mars 1971 Spacecraft

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PREFACE

The work described in this report was performed by the technical divisions of the Jet Propulsion Laboratory, under the cognizance of the Mariner Mars 1971 Project.

ACKNOWLEDGMENT

The information documented in this report was compiled by P. Alexander, J. Earnest, A. Murphy, and J. Quinn. Other personnel contributing to this effort include: G. Bummer, W. Collins, D. Davis, R. Graham, M. Maine, N. Prescott, S. Rasmussen, W. Ruthenberg, R. Seitz, W. Wuest, and T. Wujcicki, of the Propulsion Division of the Jet Propulsion Laboratory.

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ABSTRACT

This memorandum reviews the design, fabrication, and testing of the Mariner Mars 1971 pyrotechnic subsystem by the Solid Propellant Engineering Section of the Propulsion Division. Emphasis is placed on those changes from the Mariner Mars 1969 configuration. Major problems occurring in the developmental and testing phases are discussed.

I. INTRODUCTION

The purpose of this memorandum is to document the design, fabrication, and testing of the Mariner Mars 1971 (MM'71) pyrotechnic subsystem by the Solid Propellant Engineering Section of the Propulsion Division, and in particular to emphasize those changes from the Mariner Mars 1969 (MM'69) subsystem development. Clarification and additional details are given in Refs. 1 to 3.

II. PYROTECHNICS SUBSYSTEM

The MM'71 pyrotechnic subsystem consists of the pyrotechnics switching assembly (PSA), the explosive squibs on the spacecraft, the spacecraft/Centaur release devices and the pinpullers. Numerous small changes from the MM'69 design were effected in the PSA, but the basic capacitor-discharge approach remained the same. Two new squibs were developed, a completely new spacecraft/Centaur release device was designed, developed, and qualified, and minor design improvements were accomplished on the pinpullers for the MM'71 program. The basic support equipment hardware and approach were carried over from the MM'69 program.

A. Pyrotechnic Switching Assembly

The pyrotechnic switching assembly, as on MM'69, rectifies a 50-V 2.4 kHz square wave input, stores dc voltage on capacitor banks, and switches this energy upon command to fire the explosive squibs. The MM'71 PSA is shown in Fig. 1. Visible are the capacitors along the left and right chassis walls, four rows of silicon-controlled rectifiers (solid-state switches), and potted modules containing unijunction transistor switching circuits. A new function of the PSA on the MM'71 program was to supply 30 Vdc to actuate the solenoid valve on the propulsion subsystem engine. Specific changes from the MM'69 design are as follow:

(1) The propulsion maneuver selection and inhibit relays were deleted.

(2) A solenoid-driver circuit for the propulsion engine valve was added.

(3) The Mars gate control circuit was deleted.

(4) Fuses were eliminated and resistive current limiting was utilized for the transformer input.

(5) Certain subsystem functional circuits were welded and potted (such as the unijunction driver circuits and the telemetry-output circuits).

(6) One single chassis incorporating redundant channels was utilized rather than the dual-chassis approach.

(7) For system test accessibility purposes, the PSA was mounted on the spacecraft ring rather than in a case.

(8) The PSA was fabricated in-house rather than by a subsystem contract.

Figure 1 shows one side of the PSA prior to conformal coating. The two wire bundles go to the potted unijunction trigger circuits with connections to the silicon-controlled rectifiers (SCRs) placed beside and at the end of these potted modules. Twenty-four energy storage capacitors are mounted along the subchassis walls.

B. PSA Developmental History

The effects of the changes from a MM'69 design were to require considerable additional testing and analysis. However, few problems were encountered as a direct result of these changes. New problems that were encountered included some that were known to have, or could have, existed with the MM'69 design. Problems occurring in the development of the MM'71 PSA included the following:

(1) A small, though discernible, voltage existed on the capacitor banks when the PSA was in a safed (no power) configuration. This problem was a carryover from MM'69, and an early shield design fix was incorporated on MM'71 with no effect. This situation was recognized, analyzed, and handled through procedures.

(2) Current leakage through the SCRs and squib circuits was temperature dependent and did reduce the effective capacitor voltage at elevated temperatures. This was perhaps the major time-consuming problem of this MM'71 subsystem, requiring extensive testing and analysis to verify adequate energy at elevated temperatures.

(3) The PSA exceeded the specified forward (and reverse) voltages and the reverse current maxima for the flight command subsystem universal isolation switches. Considerable analysis was required to establish that these conditions were acceptable.

C. Pyrotechnic Devices

Pyrotechnic devices supplied to each MM'71 spacecraft consisted of the following: (a) two release devices, (b) five pinpullers, (c) one 1.59-cm (5/8 in.) squib for the scan platform valve, (3) fifteen 2.22-cm (7/8 in.) squibs for the propulsion valves. The release devices and pinpullers each used two 0.95-cm (3/8 in.) squibs. Although MM'71 guidelines for pyrotechnic devices were to use existing MM'69 designs wherever feasible, the MM'71 design requirements resulted in the development of a new release device, the use of the JPL-developed 0.95-cm (3/8 in.) and 2.22-cm (7/8 in.) squibs, and modification of the MM'69 pinpuller. The development, design, and test history of the MM'71 pyrotechnic devices follows:

D. Release Device

The V-band assembly secures the spacecraft to the Centaur. Two release device assemblies form an integral part of the V-band assembly. When the spacecraft is to be separated from the Centaur, electrical energy is applied (on command) to both squibs of each release device. The gas pressure of the squibs forces the piston of the device back, thereby unlocking the device and permitting one of the bolts, which is attached to the V-band, to be released from the device. Release of either device allows the V-band to relax, thereby allowing spacecraft/Centaur separation.

A cutaway view of this release device is shown in Fig. 2. The device is tensioned by applying a load at the two opposite ends – the separation bolt and the collet bolt. When the device is tensioned, the separation bolt is prevented from moving axially forward by the six tapered fingers of the collet bolt. The collet bolt fingers, in turn, cannot move radially outward because of the six pins which are placed between the collet fingers and the piston. When the squibs fire, gas pressure is directed against the piston forcing the piston backward. The piston movement allows both the pins and the collet bolt fingers to extend radially outward which, in turn, allow the separation bolt to eject, thus causing separation of the device and hence the V-bands. The separation bolt is ejected by the energy stored in the tensioned V-band. The slanted surface of the snubber receives the moving piston, absorbs the excess kinetic energy, and then locks the piston in place by wedging action.

The O-rings on the piston and gland nut contain the squib gases both during and after actuation. Two squibs fire in the device although one squib is adequate for operation.

E. Pinpuller

The four solar panels and one high-gain antenna on the spacecraft use one pinpuller each for proper retention. The solar panels and high-gain antenna are spring loaded and then latched into position and retained there by the pinpuller piston pin. A cutaway view of this pinpuller is shown in Fig. 3. When the pin is retracted the spring-loaded solar panels and antenna are deployed. The pinpuller pin is retracted by gas pressure generated against the piston-pin forcing it back. This gas pressure is developed when either of two squibs of each pinpuller (one squib is redundant) are electrically fired.

The basic MM'71 design required the pinpuller to deploy the four solar panels into their operating positions, and later in the mission to update the position of the high-gain antenna after launch. The operating conditions under which the pinpuller needed to function were, for the most part, the same as those encountered in the MM'69 mission, although minor changes were made; for example, the pinpuller connector monitor was not required.

F. Squibs

The MM'71 squibs generate pressure upon electrical command to actuate mechanisms on the spacecraft. On the MM'71 spacecraft this pressure is used to unlock the release device for spacecraft separation, to retract the pinpuller pin for solar panel and high-gain antenna deployment and to open and close the propulsion valves and to open the scan platform valve. The squib (Fig. 4) consists basically of a threaded cavity, integral with a 4-pin electrical connector. Two circuits are created by welding a thin (2-mil diam) Nichrome bridge wire between two sets of pins. A pyrotechnic mixture is placed on top of the wire and the mixture is sealed by welding on a metal diaphragm. When electrical energy is supplied to the squib through the connector end, the thin bridgewire is heated to a very high temperature and transfers heat to the pyrotechnic mixture. When the auto-ignition temperature of the pyrotechnic is reached, the mixture ignites, creating combusted gases that generate pressure which, in turn, burst the squib end closure

and enter into the particular mechanism to provide power for actuation. The whole sequence of electrical application to pressure generation of the squib involves a very short time — less than 10 ms.

The MM'71 squib fabrication program consisted of manufacturing development of a 2.22-cm (7/8 in.) squib for the propulsion valves, a 0.95-cm (3/8 in.) squib for the pinpuller and release device, and requalification of surplus 1.59-cm (5/8 in.) squibs for the scan latch.

A squib was sought with as many features useful to the spacecraft as possible within the state-of-the-art. It was required that the squib be structurally sound and shock resistant at temperature extremes. Dual ignition circuits were required to provide reliability in explosive valves and other devices where two cartridges were not practical. Safety requirements dictated a 1-W/1-A no-fire level. Protection from handling static discharge was built in. This is required between the circuits as well as pin to case. The extremes of human-induced static charges were assumed to be 25,000 V from a 500-pF capacitor through 5000 Ω. Hermetic seals and long storage life were also important. The same initiation elements were used in both the 0.95-cm (3/8 in.) and 2.22-cm (7/8 in.) squibs.

Lot acceptance tests of the flight-quality squibs were conducted at the squib contractor's facility for JPL buyoff. The squibs were then brought into JPL where flight-acceptance and type-approval (TA) tests were conducted on the squibs per JPL test specification TS 504518. The TA tests were designed to expose the squibs to all possible environmental modes the squibs might encounter before, during, and after spacecraft installation and flight. In addition, margins tests were conducted on numbers of squibs to determine the limits of squib performance. These limits in many cases exceeded spacecraft requirements.

The 0.95-cm (3/8 in.), 2.22-cm (7/8 in.), and 1.59-cm (5/8 in.) squibs passed all the Project test requirements of TS 504518 and TS 503665, respectively, and were deemed qualified for spacecraft flight use.

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1. "MM'71 Pyrotechnic Subsystem, Preliminary Design Review Report," JPL Internal Document 610-89, Jet Propulsion Laboratory, Pasadena, California, June 30, 1969.

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3. "Mariner Mars 1969 Final Project Report: Development, Design, and Test," Technical Report 32-1460, Vol. I, Jet Propulsion Laboratory, Pasadena, California, Nov. 1, 1970.

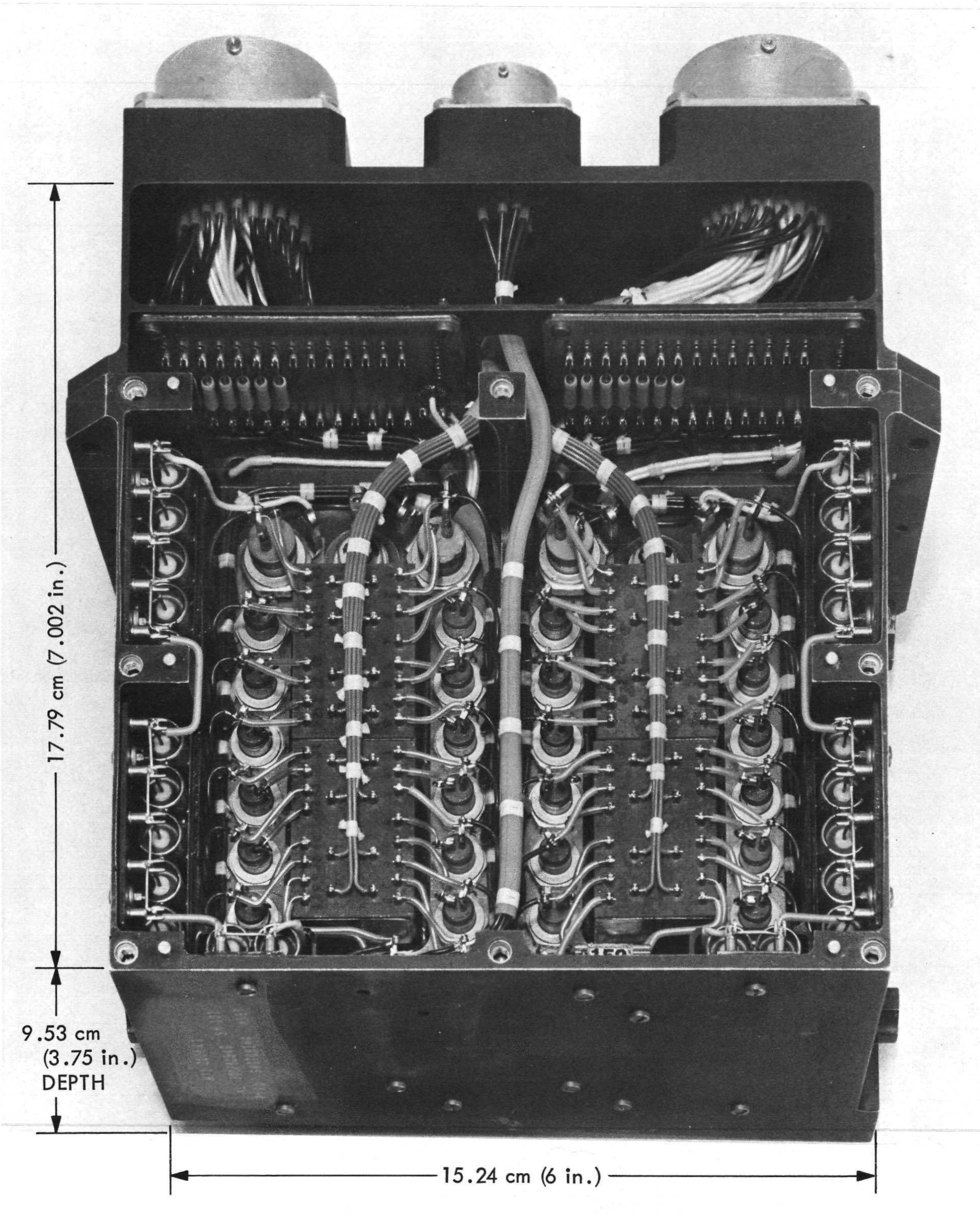

Fig. 1. Pyrotechnic switching assembly

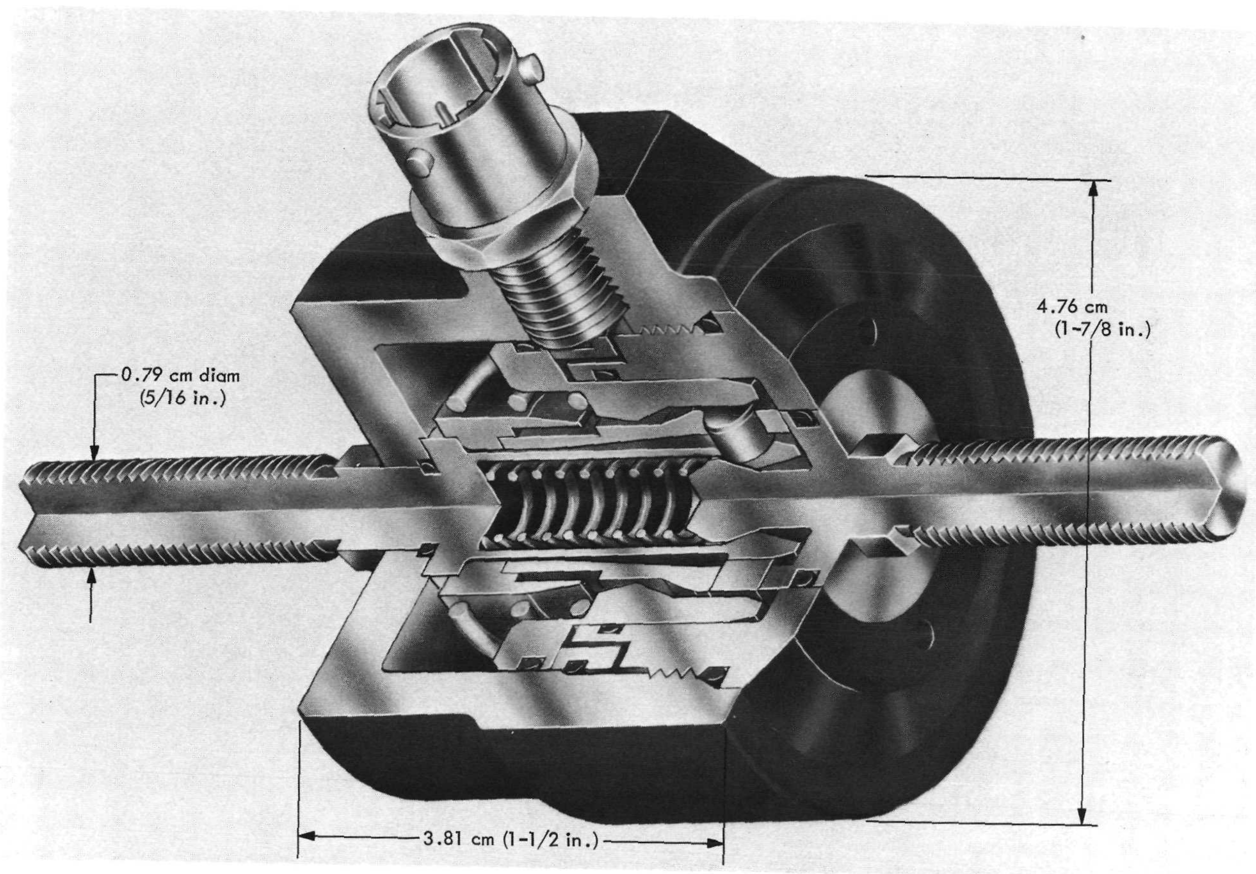

Fig. 2. Pyrotechnic release device

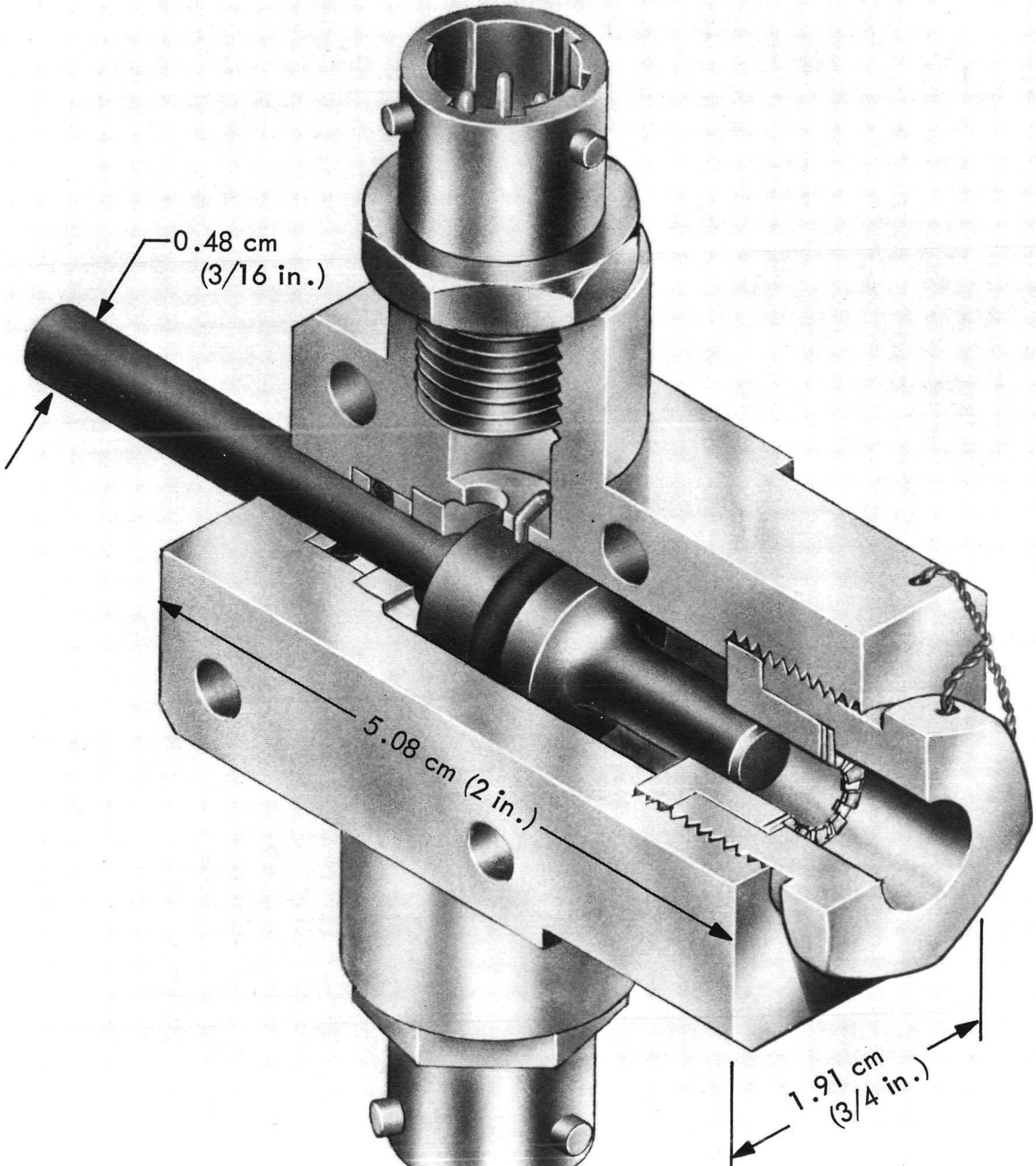

Fig. 3. Pyrotechnic pinpuller

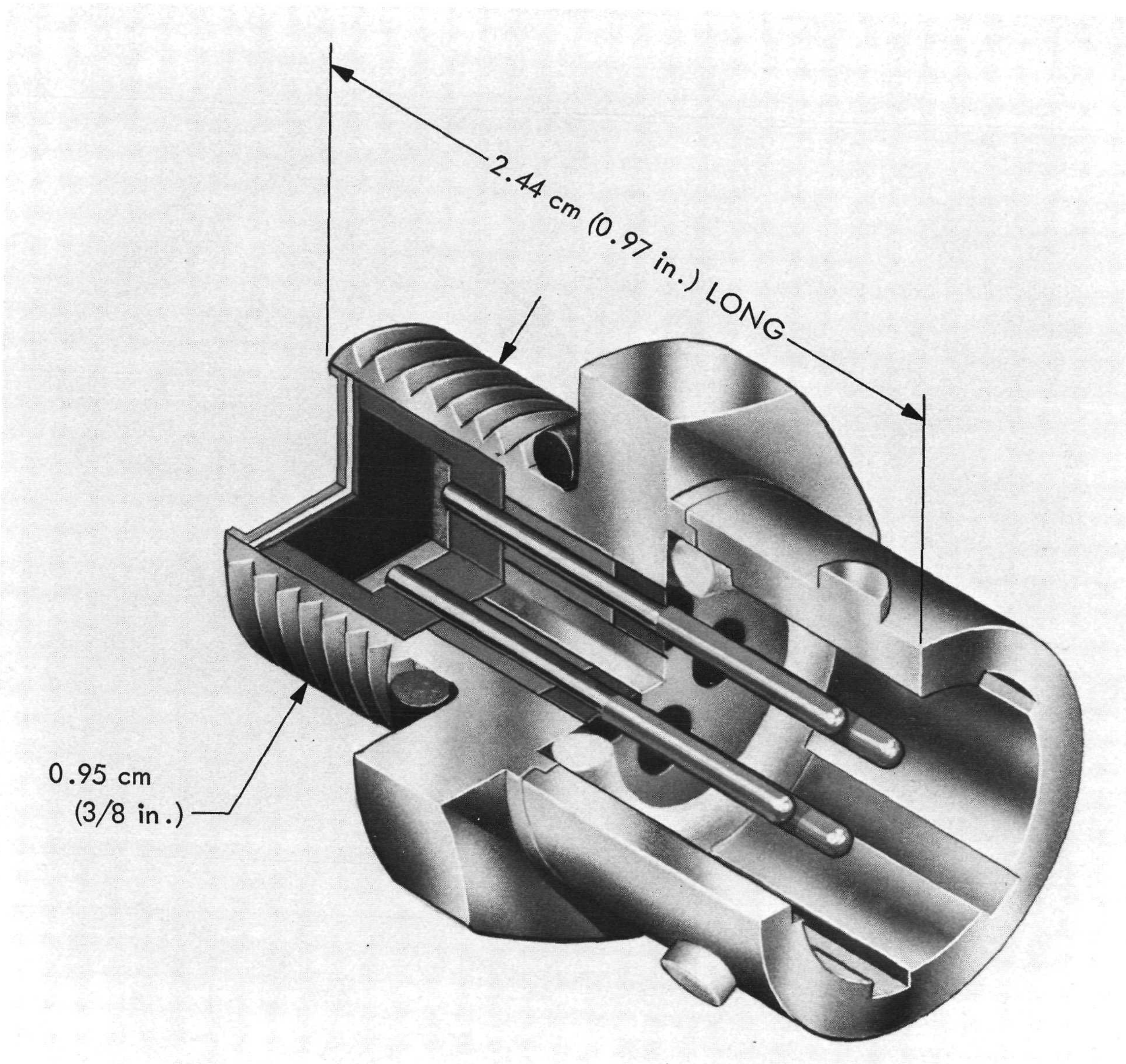

Fig. 4. Dual bridgewire squib

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